TAMPERE UNIVERSITY
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OPTIMISATION IN DIGITAL COMPOSITING - A Case Study on Nuke

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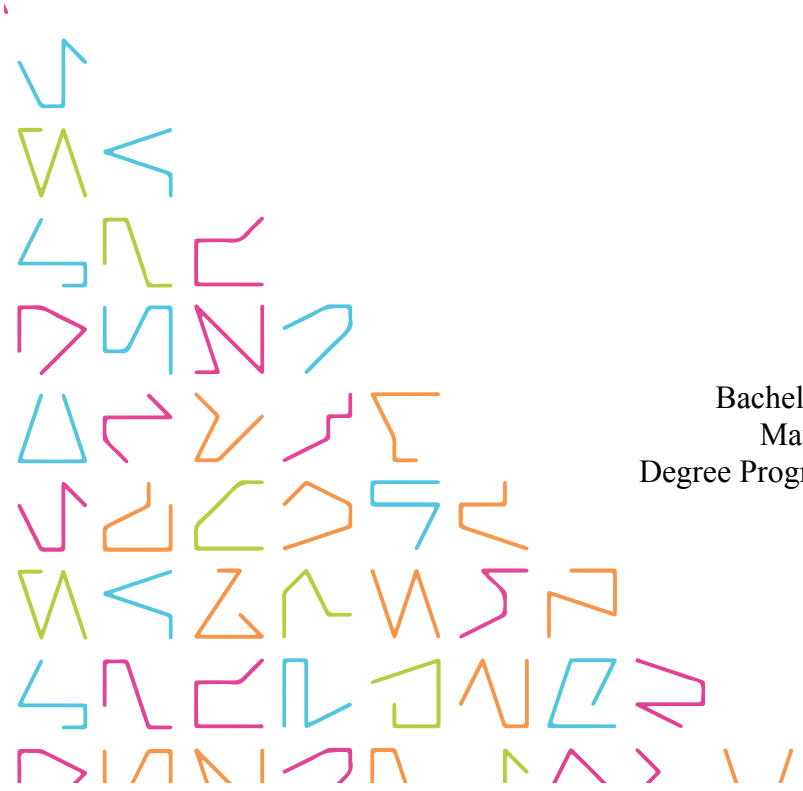

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ABSTRACT

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Digital compositing is an artistic process, but, at the same time, it is a very technical topic and requires appropriate knowledge. Post-production departments almost always work under time pressure, and artists need to keep a fragile balance between budget, quality and time. Therefore, process optimisation is a vital consideration. Another reason is that plenty of people come to the business self-educated and from freelance backgrounds with their own habits, which quite often can harm and slow down the process of digital compositing.

The purpose of this thesis was to explore, to analyse, and show the ways to optimise the day-by-day process of digital compositing in order to shape appropriate habits from the beginning of a career. In this work, not only the technical aspects of optimisation were necessary to research, but also behavioural aspects of optimisation. From all the compositing software, Nuke was chosen for the case study, because it is one of the most popular and utilised programs in the modern professional world of digital compositing.

The understanding of which aspects should have been considered was reached through comparing information from reliable sources such as literature, lectures, tutorials from renowned compositing artists, and information collected through the author's personal experience in university projects and working in post-production departments of two different companies. At the same time, the comparison was the main source of data collection and analysis.

As a result of the study, it is possible to see that optimisation can essentially speed up the process of digital compositing and improve the quality of work for teams and individuals.

This topic can never be completely covered since the compositing world develops at a high pace. Obviously, following monthly or even weekly updates of tools is also essential for improving the quality and speed of work. However, some basics will always be basics and knowledge about them is key to future development.

Key words: digital compositing, optimisation, nuke

CONTENTS

1 INTRODUCTION

Although when I started my program in Tampere University of Applied Sciences I did not know what digital compositing was, during four years of studies, I have had the possibility to experience many areas of media design, and digital compositing was an obvious choice. I always tended to combine different techniques in all my projects; an animation could not be just an animation, and a video could not be just a video. Moreover, during the second year of my studies I got interested in lighting, and regularly assisted a student of film and television who experimented with complicated lighting and camera techniques. Therefore, when I had to choose my major there were no doubts about digital compositing, purpose of which, generally speaking, is adapting different images and techniques to each other including, of course digital lighting.

Now, having undertaken some large projects in university and work experience in two companies, I can see what blank spaces I have in my knowledge. Therefore, I am grateful to have the possibility to write this work.

I hope that this work will be interesting and useful for other compositing artists. Since digital compositing is a dynamic area, and artists work consistently under time pressure, many of them didn't have the possibility that I have now – to stop, to organize their knowledge about the basics and to improve their techniques. This fact doesn't make anyone a bad artist but, considering that digital compositing is really technical area, can lead to obtaining bad working habits and slower work.

In this work, I have tried to cover as many aspects as possible which can improve and speed up the process of digital compositing. Some of them could seem somewhat obvious but, relying on my own observations, for artists with freelance backgrounds, for those without experience of work in post-production department or, for beginners, they are not. Some of them I see as important techniques which even experienced artists don't always remember.

1.1 Need for optimisation

The easiest definition of the term “optimisation” would be to make the best or most effective use of situation or resource. In terms of digital compositing, it means a production of the highest quality images in the most efficient way (Brinkman 2008, 327).

The need to raise a topic of optimisation in digital compositing comes from specifics of the area. Post-production departments are almost always under the time pressure, which is why artists almost never have time to produce perfect composites. For people who are paying for the work, speed, quantity and cost often are more important than quality. This is the reason why every artist should have his own tricks and methods of how to deliver his works according to a fragile balance of budget, quality and time, and why every artist should know how to optimise composites. Therefore, it is important to know some certain basics; where it is possible to minimize efforts and get the same quality, and where other tricks will destroy the quality.

Another important detail about the digital compositing business is that the area is relatively new and developing at a high pace. These facts make standards of the industry fragile. Many people entering the business are self-educated and therefore, even with great composites, may have some knowledge gaps. It touches upon not only the technical aspects of digital compositing but also behavioral aspects such as etiquette of group work. These can slow down the work process and lead to late delivery of a product. This is another reason to consider the topic of optimisation.

In addition to fragile standards, there are plenty of non-reliable learning sources. Almost all of the artists learn new techniques through video tutorials mostly posted on such websites as Youtube or Vimeo. It is possible to find indispensable materials from these sources but, at the same time, there are plenty of amateur and misleading tutorials. For experienced artists, it is easy to differentiate good tutorials from bad but, for beginners, it can cause trouble in a future development because incorrect techniques can easily become a habit.

This work is mainly concentrated on optimisation of day-by-day workflow. For compositing artists, being efficient should be natural because quite often the process of digital compositing can be unbelievably complex. Of course, to be able to fully focus on visual

aspects and deal with complicated technical tasks, artists need to be automatically, able to work efficiently, build clear and understandable scripts, have good time and file management, understand their roles in a team, and perform day-by-day operations in a smart way.

1.2 Structure and approach

Optimisation in digital compositing is a huge topic to research, and it can be approached from different angles. This work provides general ideas about ways a workflow can be optimised. As previously mentioned, the main purpose of the work is to form correct habits from the beginning of a career, and highlight the areas about which an artist shouldn't forget.

The work has 5 chapters. The aim of the first and current chapter is to introduce all the purposes and approaches to the reader. The 2nd chapter, "Digital Compositing", provides information about the digital compositing world; what digital compositing is and how it developed, what its role is in the visual effects pipeline and which software programs are commonly used.

The 3rd chapter, "Optimisation through organization", advises about project set ups and script building. Organized and understandable scripts along with clear and readable file names are extremely important for digital compositing. It brings personal comfort to an artist, allowing him to think more clearly. Importantly, it also makes team work possible.

Unfortunately, it is hard to place some topics on one or another chapter because they cover multiple aspects. For example, the sub-chapter about rendering is primarily about organization, about which direction a company or an artist can choose to go but, at the same time, rendering is a completely technical process. This sub-chapter is in the organization chapter because this work is introducing possibilities of organization of rendering processes but doesn't provide any strong technical advice or solutions. The same situation happens with such sub-chapters as expressions and gizmos. These topics are so complex that if they were to be researched deeper in terms of optimisation, each of them would be longer than this entire thesis.

Additionally, the 3rd chapter includes a discussion about rotoscoping. As stated above, the purpose of this work is to concentrate on general rules and advice for workflow optimisation in Nuke, and not to go deep into certain areas of compositing. However, as an exception, a small subchapter about optimisation of rotoscoping processes is included to this work. VFX (visual effects) houses have devoted artists for rotoscoping but right roto-habits will serve every artist during his/her career because these skills are needed in many areas of post-production. For example, moving objects in a shot quite often have to be masked to allow camera trackers to function better. Masking is also often needed during a keying process. Even color correction artists need to animate masks.

"Technical Optimisation" is the 4th chapter which consists of general advice about reducing processing time for every area of digital compositing. The subchapter about reduction of operations could also be placed in an organizational chapter since it makes script cleaner and more understandable, but in this case priority was given to the processing time issue.

To conclude this part, it is important to mention that, from the beginning, it was planned that the thesis includes a chapter about team work. However, a lot of aspects reviewed in this work are suitable for both individual and team work. Nevertheless, at this point, an emphasis should be placed to concentrate attention of the reader on the importance of being a good team member in terms of optimisation.

1.3 Sources

The aim of this subchapter is to introduce to the reader the current situation in the digital compositing world, in the educational sense, and to explain or to justify the sources which were used for this research. It is important to stop and to review this issue because truly successful optimisation processes can be built only on appropriate knowledge.

Traditionally, books are considered as the most reliable sources for research. However, everyone knows that with the appearance of the Internet, things changed. Of course, from one side, information became more available. From another side, the quality of the information decreased. This aspect should be considered during the research process.

Another thing to keep in mind is that digital compositing is quite a new industry and a rapidly developing one. By putting together these two aspects, it is easy to understand that there are not many books were written about digital compositing, and those that exist may be out of date. Consequently, more questions appear: what sources should be used and, if information comes from the Internet, what sources are reliable?

There are a few books that have become icons for digital compositing. They describe basics and main principles which remain constant. Therefore, relatively, it doesn't matter how old is the book because in the world of digital compositing "0" is always going to be black and "1" is always going to be white. Even if new features appear every day, every artist should know the basics to understand what is behind these new features and automatically made processes. One of the most famous books about digital compositing is "The Art and Science of Digital Compositing" by Ron Brinkmann with the last edition in 2008.

Books provide well-structured appropriate information and able to give a good solid start. Nevertheless, this work is made on the example of particular software, Nuke, what means that a lot of information from books might be too general. Indeed, artists tend to specialize on certain software programs, therefore they need more specific knowledge. Even if there is a book or two about using Nuke, most updated information comes from the Internet. Also, because of the specifics of the area, it is hard to explain certain things in books; they need visual representation in motion.

Mostly, knowledge in digital compositing comes from experimenting and sharing. There are plenty of articles and video tutorials made by famous artists and available in the Internet. A lot of video tutorials are not just about showing techniques; they are like complete lectures from professors with a great theoretical background. The only problem is reliability: if an artist doesn't have a lot of personal experience to judge the quality of learning materials he should be careful with picking things from such sources as Youtube or Vimeo. That's how wrong techniques and habits become natural for artist's workflow.

A source of help for Nuke artists is Nukepedia which provides articles, written tutorials, gizmos and so forth that can be useful for compositing in Nuke. Fxguide is another online community for searching reliable materials. It has two departments: Fxguide, which pro-

vides articles and interviews, and Fxphd, which is membership based training site. Unfortunately, tutorials from Fxphd are free of charge, but nevertheless are some of the best in VFX educational world. Also, such payed sources as Lynda and Pluralsight should be mentioned. Ron Brinkmann and Steve Wright, whose books were used for this work, have online tutorials on the above mentioned platforms.

It is also possible to find free and reliable educational materials from some professionals. For example, a web page from Tony Lyon with a Youtube channel named “CreativeLyonsTuts” or the “Eosacro” channel on Vimeo. Additionally, Foundry by itself provides learning materials.

2 DIGITAL COMPOSITING

2.1 What is digital compositing?

Digital compositing is the process which deals with the integration of images from multiple sources into single one in such way that they look like that they have been shot at the same time, under the same lighting conditions and with the same camera (Brinkmann 2008, 2; Wright 2010, 1). Compositing is used in the world of films, games, television and short form content. To understand better the world of compositing it is necessary to explain what those "images" are that need to be integrated, and for what purpose.

The world of filmmaking and video production consists of five main stages: development, pre-production, production, post-production and distribution (Steiff 2005, 26-28). All the stages which include the word "production" are connected to an image creation process. Pre-production includes a careful planning of all the images which are going to be involved in the compositing process. Production is the part responsible for making images, which can be hand-painted or human-generated elements, computer generated imagery (CGI) or images that have been digitised from some other source (usually film or video). Compositing, which integrates all the images from production, belongs to the third stage - post-production, and is considered to be one of the final steps in the whole production. Usually, only the color grading process follows digital compositing in post-production. More precisely the place of compositing in the VFX workflow can be seen in the scheme below (figure 3).

The best way to explain digital compositing is through a visual example. The sequence of the images in picture 1 shows all the elements of compositing separately, together and together under the same lighting and color conditions.

If the shot demonstrated in picture 1 represents so much compositing work done then it would be almost impossible to demonstrate in this thesis how much steps would be required for the look of a more complicated shot (picture 2).

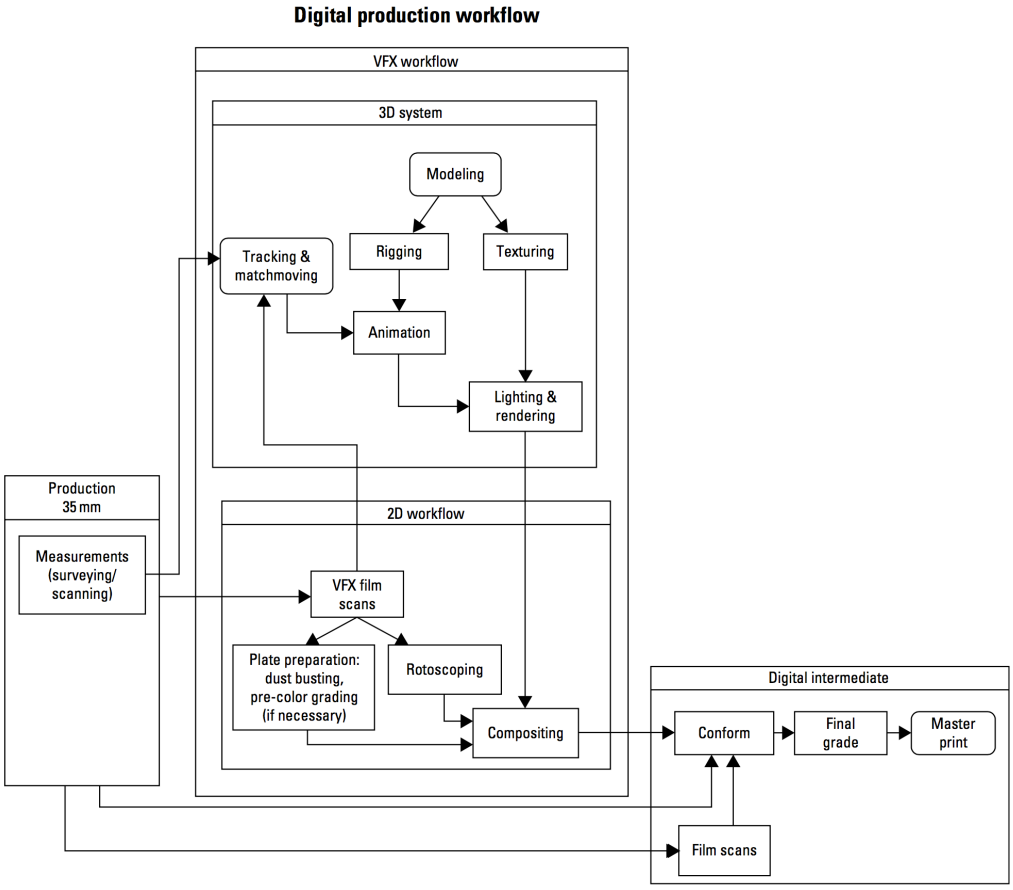


FIGURE 3. Digital production workflow (Kidd, 2010)

PICTURE 1. Still images from VFX Breakdown of Breaking Point (Lapp, M. 2016, modified)

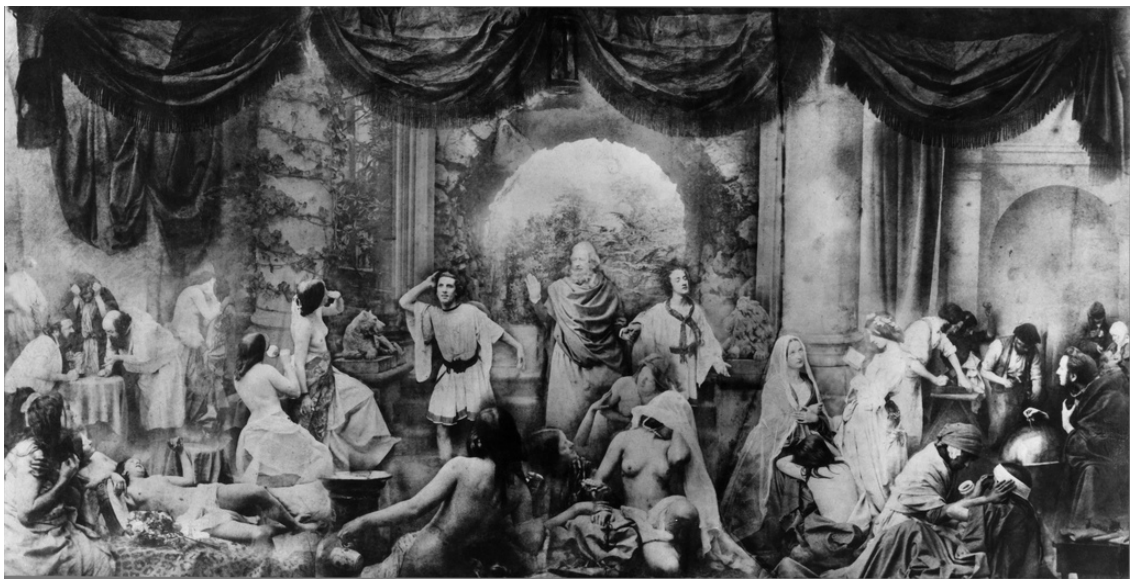
PICTURE 2. Still image from Breaking Point (Lapp, M. 2016)

2.2 History of digital compositing

From a historical perspective, digital compositing takes its roots from the summer of 1857 when the photographer Oscar G. Rejlander created the most technically complicated photograph of that time. His work, The Two Ways of Life, is a combination of 32 different glass negatives (picture 3). The process of combination was required to partly uncover certain portions of the printing paper and expose the chosen negative to that area. It was one of the earliest examples of combination print. (Brinkmann 2008, 3, 5)

It would be more time-consuming and expensive for Rejlander to bring this idea to life without a combination of negatives. He would need a big studio and a lot of models. Also, combination allowed the artist to work on the pose of each model more precisely and get more desirable results.

A the time “The two ways of life” was quite controversial work because such photography manipulation was not ethically and artistically valuable. However, Rejlander’s techniques were continued to be used and developed.



PICTURE 3. The Two Ways of Life (Reijlander, O. G. 1857)

The appearance of motion picture in the 19th century facilitated the development of image combination. New technologies such as optical printers, which were able to combine multiple pieces of film, gave birth to optical compositing. Even nowadays, when compositing is made on computers, techniques and skills of that time can be easily recognised.

The film ‘The Four Troublesome Heads’ by Georges Méliès can be a great example of one of the first steps of optical compositing (picture 4). The technique of multi exposure is used to show 3 copies of one head.

It is hard to say when exactly optical composting transformed to digital compositing; which is just the digital analogue of the first one. According to Wikipedia (2017), computer animation started its history in 1961. Of course, animation is not compositing but they are related, and the same techniques and operations quite often are used in both fields.

PICTURE 4. Scene from The Four Troublesome Heads (Méliès, G. 1898)

The next important step in the history of digital compositing can be greatly described by one of the inventors of alpha channel - Alvy Ray Smith (1995): “Ed Catmull and I invented the notion of the integral alpha in the 1970s at New York Tech. This is the notion that opacity (or, equivalently, transparency) of an image is as fundamental as its color and should therefore be included as part of the image, not as a secondary accompaniment. To be very clear, we did not invent digital mattes or digital compositing. These were obvious digital adaptations of known analogue techniques. We invented the notion of the alpha channel as a fundamental component of an image. We coined the term “alpha” for the new channel. We called the resulting full-color pixel an “RGBA” pixel. Thus RGB images (Red, Green, Blue) became RGBA images (Red, Green, Blue, Alpha) in all work done by the Catmull/Smith team from that point forward, including Lucasfilm and Pixar.” Nowadays, it is hard to imagine almost any digital compositing project without a use of the alpha channel, and as such this invention is so highlighted in the history of compositing.

Digital compositing software by itself appeared as recently as in the 1990’s. The most historically valuable nonlinear compositing system was the Cineon invented by Kodak in 1992. One year later, in 1993, software programs like Nuke, After Effects, Flame appeared.

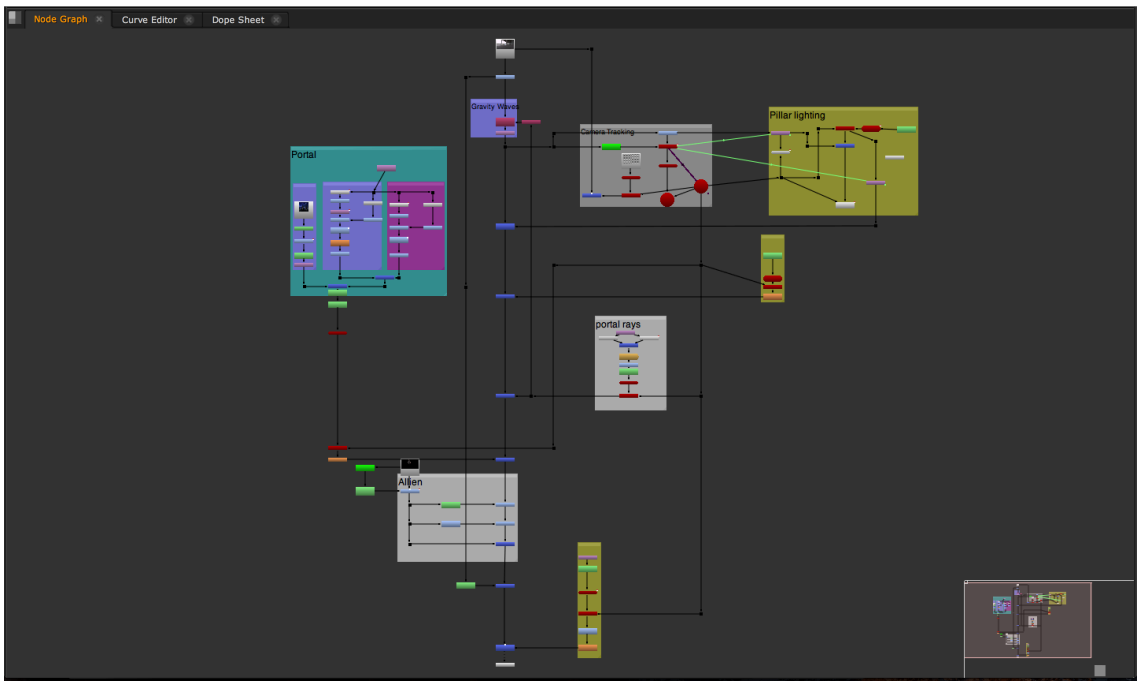
2.3 Compositing software

2.3.1 Overview

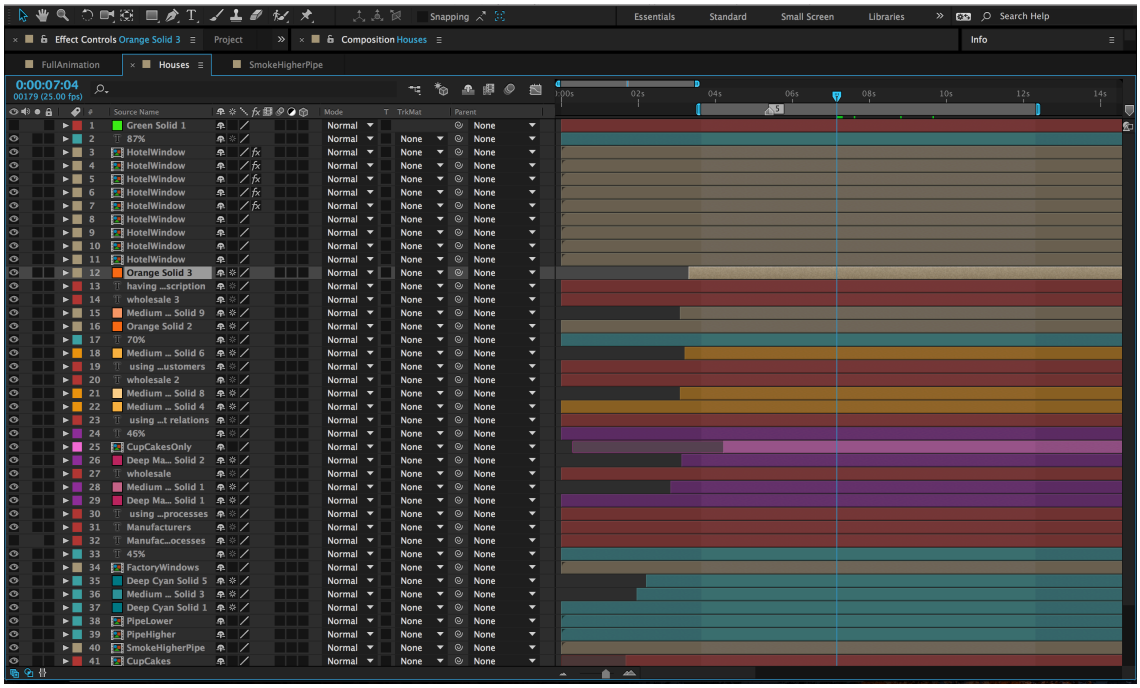
Nowadays the market of digital compositing software can offer a great variety of programs. Some programs are more multi-proposal and can deal also with motion graphics or 3D, for example. Some programs are so expensive that only large production houses can afford them. However, if we were to start categorise compositing software programs and digital compositing, in general, the main division would be layer-based and node-based compositing (software). These are two completely different types of workflow.

In node-based compositing, all sources and operations (effects) are represented as nodes. The most acceptable and suggested, by professional artists and developers, way to organize nodes into scripts is a method referred to as “The Tree”, “The Spine” or “Vertical Script Flow” where all the nodes together form a structure in a shape of a tree which shows an interconnection of all the operations (Djordjevic 2012). The tree is built from top to bottom: starting from sources and ending with a final result (picture 5). The whole composite is built by merging branches (sources) of the tree.

In layer-based compositing, all sources are represented as layers, shown within a timeline, and all the operations (effects) are stored inside of the layers or applied on the top of all the layers (picture 6). The composition is built by storing layers on the top of each other. (Hedin 2010, 6)



PICTURE 5. Example of node-based compositing software (Nuke) interface (Pak, Y. 2016)



PICTURE 6. Example of layer-based compositing software (Adobe After Effects) interface (Pak, Y. 2016)

Node-based compositing is more on demand in the VFX world. However, a lot of artists know how to work with the most well-known layer-based software program - Adobe After Effects, because this software is probably the best to work with motion graphics and, at the same time, it is possible to compose within it.

What exactly makes node-based compositing more efficient? Usually these types of software provide more powerful tools with a greater number of features. Artists also have more control over an image. A lot of packages, including Nuke, allow users to have programming input. Whereas layer-based software programs perform many effects automatically, node-based ones allow for control of every step of an effect creation. For example, working with channels as separated pieces in such layer-based software as Adobe After Effects is quite complicated task. At the same time in Nuke, a Shuffle node, which is separating channels, is one of the essential operations. It is possible to create new channels, to divide, to combine them and to do many more operations. A lot of nodes have a controller which allows for the choice of channels that will be affected by the node.

Another point of note in node-based compositing is that information can be perceived more easily, because it is possible to see all the sequences of operations and thus the logic of actions. This fact allows users to find new decisions and to fix mistakes faster. Therefore, for big projects it is far more comfortable to use node-based compositing packages. However, some small projects or modifications might be easier to do in layer-based programs.

2.3.2 Nuke

The case study of this thesis is Nuke because it is one of the leading and utilised software programs on the market. Nuke is a node-based family of compositing software programs which consists Nuke (basic, 1993), Nuke X (Nuke + advanced 2D and 3D tools, 2010) and Nuke Studio (Nuke X + editorial and review tool, 2014).

Nuke was created in 1993 by Bill Spitzak in American company named Digital Domain. The program spread fast and was already used in such movies as True Lies (1994), Apollo 13 (1995) and Titanic (1997). In 2007, English company The Foundry, which previously concentrated only on plug-in development, obtained the rights for Nuke. Soon after, the software became a standard in film pipelines around the world. In 2012, the core family of Nuke expanded with Nuke Assist. (Kyneur 2015)

As it was mentioned above, some compositing software programs are quite expensive, some of them have student editions for free or at a reduced price, however, it still makes them completely inaccessible for a non-student person who just wants to learn and to experiment. However, regarding Nuke, the Foundry revolutionised their product when in 2015 they launched a non-commercial version of the software which is available for all, and has just a few limitations in comparison to the full version. This fact made Nuke's position on the market even more stable.

Nowadays, great number of movies with high quality special effects are made with Nuke and other products of The Foundry. "Star Wars: The Force Awakens", "The Magnificent Seven", "Deadpool" and, the revolutionary movie "Avatar" are great examples. The software is not just used in high-budget movies but also in a great amount of small and medium size production houses around the world.

3 OPTIMISATION THROUGH ORGANIZATION

3.1 Set a project

A project which is set in an efficient way from the beginning can save a lot of time. Good time management is incredibly important for compositing artists. Since digital compositing doesn't have any strict rules of how to reach a certain result, it is always a call for an artist: how can one reach the best results in a shorter and smarter way? For example, the same process can be set in 30 minutes by the artist and then be processed by the computer during 9 hours, or it can be set in 2 hours and be processed 2 hours. Of course, the decision will depend on the time of the working day: if it is beginning or the end. It seems obvious but it is always important to remember that the job of a digital compositor is full of such trade-offs. Usually the ability to take these decisions comes with experience and is referred to as "production sense". (Brinkmann 2008, 329)

To estimate the time which will be required for a project, it is essential that an assessment is made, because digital compositing is always on the balance of time and quality of the work. Only based on this assessment can an artist understand what his possibilities are within a certain project and how a final result should look.

Aleksandar Djordjevic, New York based visual effects artist and supervisor, advises to answer the following questions in order to assess work:

- What is the task?
- Does it require to key stuff?
- How much roto-work awaits and is there a dedicated roto-artist on the job?
- How much tracking work awaits and is there a dedicated matchmoving artist on the job?
- Does it have some amount of 3D projection work to be done?
- Is the 3D projection work on the foreground or on the background?
- Everything the artist can possibly think of, compositing related. (Djordjevic 2010)

Another set of questions advised by the same artist is about personal review of the work when it is done:

- How are the edges?

- How is the tracking?
- Does the foreground live in the same world as the background (color-wise)?
- How is the grain?
- What might the VFX supervisor have comments on? (Djordjevic 2010)

It might look obvious but it is important to go through all of them before submitting the work. Reviewing processes by supervisors and other members of production team can take a lot of time, as well as rerendering fixed materials after the review.

Sometimes it might be hard to fairly review personal work after hours spent on looking at the same material. Therefore, it could be helpful to watch the work under different visual circumstances: put gamma up and down; look at it under the show LUT (Look Up Table) or under different LUT's; go up and down the script; look at each channel individually; look at individual frames as at pictures.

3.1.1 Check-Up List

In the beginning of every project it is necessary for an artist to accustom himself to making and checking all the settings. It should become a natural habit and be done automatically. Sometimes under time pressure or during many hours of work even a professional artist could miss some settings and then struggle with finding a mistake in a script.

Usually most of the required settings can be made in a project settings tab, in a viewer settings tab, in a Read node and with some additional nodes like a Shuffle node or a Reformat node. Typical check-up list for a project could consist following points:

- Set correct frame rate and format;
- Check what is the right colorspace for a project and for all the files;
- Have correct frame range for a project and all the files; make offsets if it is needed;
- Create a proxy file if it is needed;
- Set all the right channels for read in files;
- Make conversions for files if it is needed. For example, by default EXR files rendered from some 3D applications like Autodesk Maya are tile based. At the same time, Nuke works faster with scanline rendered files. It could be better to rerender heavy EXR files from tile based render to scanline based. Another great example

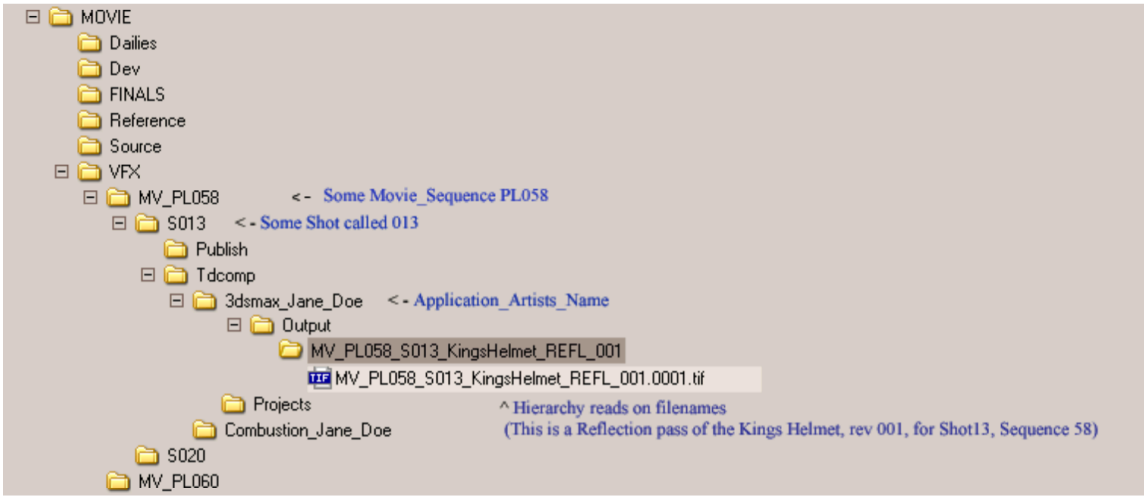
which also covers previous clause, is to rerender EXR channels into separate sequences. Nuke reads faster separate files then extracting it from one EXR sequence; (Glick 2011)

- Set a safe zone and other necessary marks for a project;
- Create suitable workspace for a project. Usually artists have their own presets.

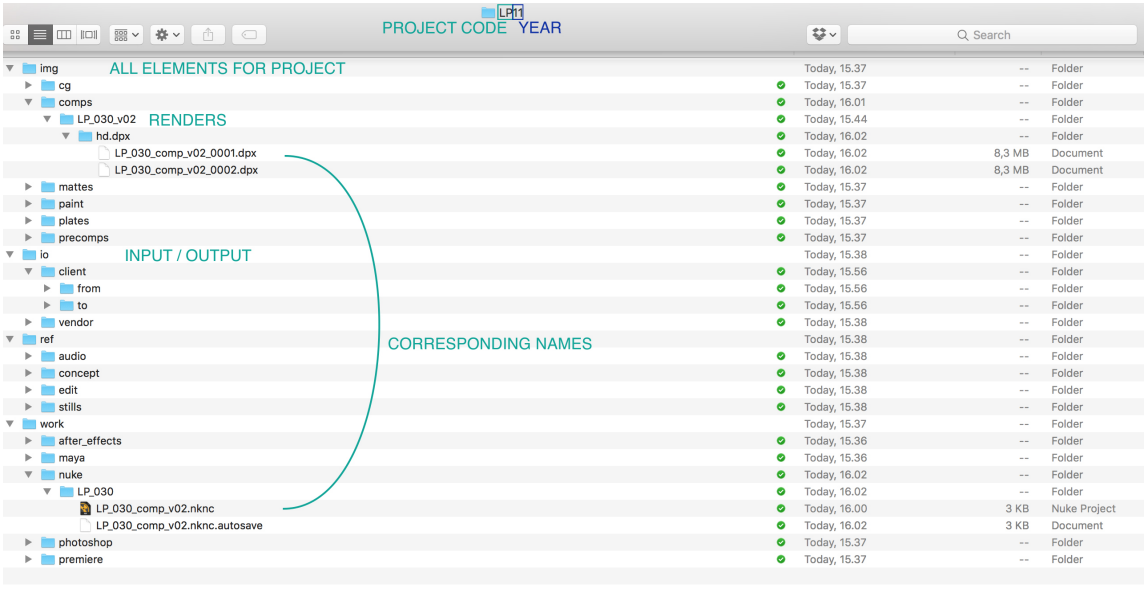
3.1.2 Naming Conventions

Something every artist should know is the right way to name files and folders within a post-production world. It is incredibly important to keep all the files with appropriate names and in appropriate locations. It is vital for individual work but for team work this aspect is crucial. Noncompliance of naming convention and file structure can not only slow down the work but can lead to the delivery of wrong results and to duplicating work.

From company to company, rules of naming files and folders can slightly vary but, generally, the principle of a naming methodology according to industry standards is from general to specific. Everything starts from creating a Master Hierarchy which should be identical for all the projects. Every artist involved with a project should understand where to take files from and where to store files. In the images below, there are a few examples of how master hierarchies could look (Picture 7, Picture 8). (Moses 2007, 1)



PICTURE 7. Master Hierarchy (Moses 2007)



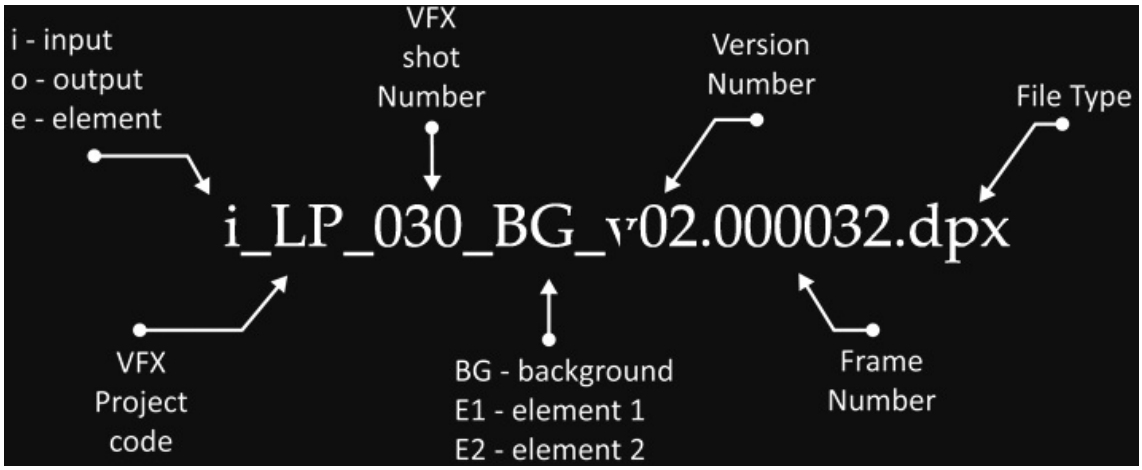
PICTURE 8. Master Hierarchy based on Jeremy Brown's example (Pak 2017)

By comparing images provided above, it is obvious that they differ one from another significantly. However, they follow the same logic. The Master Hierarchy based by Matt Moses seems like a structure for a bigger company than the Hierarchy based on Jeremy Brown's example (picture 7, picture 8). The first one has more strict separation of departments and names of artists assigned to folders.

Two hierarchies presented are applied for the whole post-production department. It is important that every branch of post-production department follow the same rules of naming; even if for one artist some information in a file name is not needed, it could be essential for another.

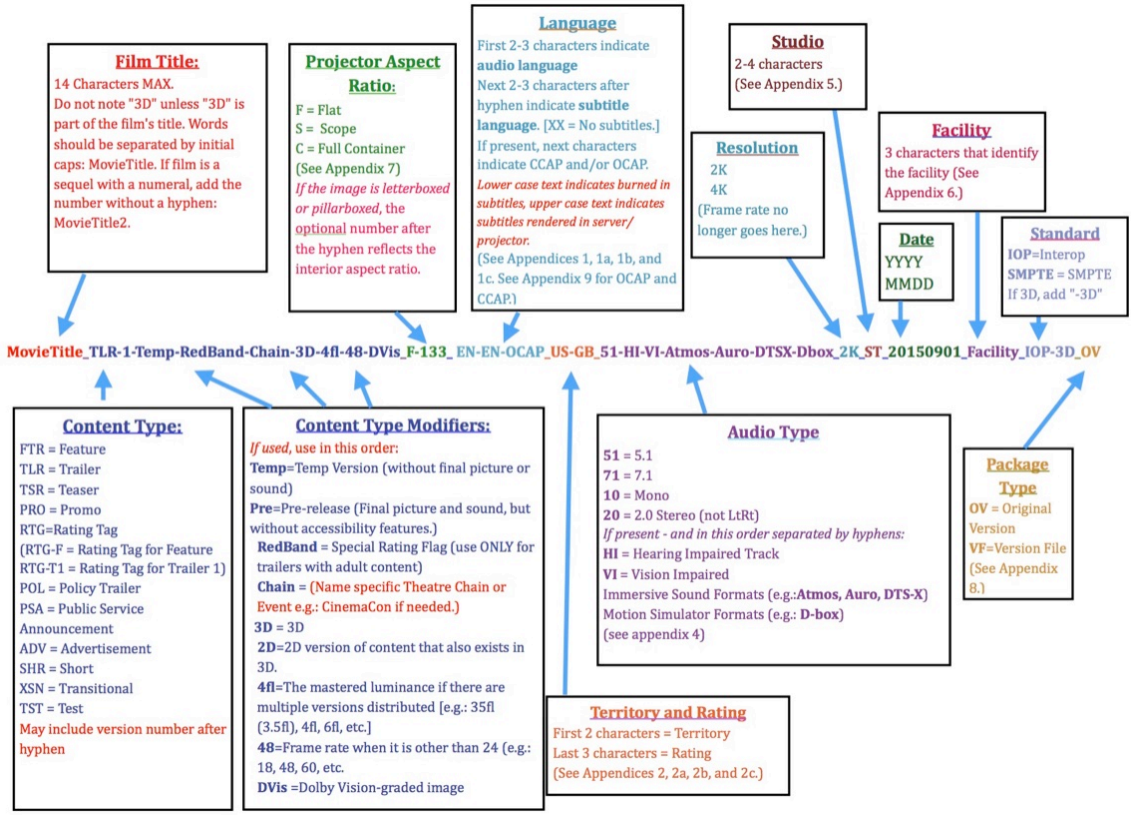
Speaking more precisely about naming files, they should be named in the way that it is possible to trace their path back through the hierarchy. An example of the file name which corresponds to standards of modern VFX world is presented below (picture 9). The first letter of the name can stand for input when materials are sent for post-production, for output when materials are sent back from post-production, or for elements when materials are created by an artist. A VFX project code is usually first letters of the full project name. For example, LP could stand for a commercial named Light Pasta. Next goes the number of the shot. If it is relevant for a project between project code and shot number, scene number can be placed. After goes classification of material for a shot. It can be background, foreground or a name of additional elements for a shot (e.g. fire, smoke, dust). The last abbreviation before dot stands for a version number. Even if a file has just one

version, it still should be mentioned. All the information which goes before the first period can be used as a name for a folder where the sequence is kept. The information which goes after the first period represents a frame number, which usually starts with 1, and a file type. (Mantri 2014)



PICTURE 9. File naming (Mantri 2014)

The length of the name, of course, depends on the size of the company and on departments in which files circulate. Depending on the need the file name can be shorter or longer. For example, both hierarchies presented above don't have input or output designation, and it is not incorrect (picture 7, picture 8). Simply, for those companies and the hierarchies they built, these pieces of information are just irrelevant. It is important to understand what information should be in the file name and what information can be omitted. Obviously, too long file name will be uncomfortable and hardly readable (picture 10). This example shows other possible abbreviations which can be included to the name of a file in digital cinema world. Of course, to digital compositing department files don't need to have information about audio or language but, anyway, artists of every department should understand the industry.



PICTURE 10. Digital cinema naming convention (Inter-Society Digital Cinema Forum)

3.1.3 Render

"Rendering is an art of trying to cheat compromises" (Seymour 2012). Rendering is a huge topic to discuss in the VFX world. Big companies are constantly searching for new solutions to render their projects because it is all about saving time and money. However, it would be more suitable to research the rendering topic deeper if this work was more 3D oriented or concentrated on specific sizes of companies. At the same time, it is impossible not to mention this topic in terms of optimisation, especially now, when Nuke's 3D possibilities are getting stronger and stronger.

In every case, rendering depends on many conditions. For example, if it is an individual project then there is no need to speak about render farms because it is unlikely that there are people who have them at home. Also, rendering solutions for small and big companies are different. Nevertheless, rendering time should be always considered when planning a project. It could be a quite challenging thing to achieve, because schedules in the industry

are often fluctuating and time for rendering of the final outcome is sometimes hard to predict.

To optimise rendering process different plug-ins are used but most of them are for specialized 3D software. Nevertheless, as it was mentioned above, Nuke's 3D side is getting stronger, therefore there is a need to make plug-ins which can work with Nuke. For example, one of the most famous plug-ins' V-Ray' was launched in Nuke's 2015 version (Seymour 2015). Using V-Ray and Nuke together halves the workload of the final renders. "I realized that we were compressing two previously discrete steps into one. It was a change in thinking" says Jesse Spielman from famous VFX company Framestore. V-Ray for Nuke brings a big change for the visual effects industry. It allows lighters, compositors and modellers work together in one piece of software. (Chaosgroup 2016)

Of course, 3D, in terms of modelling or texturizing, is out of direct compositing artist's responsibilities but, at the same time, they need to work with it a lot. In small companies, it often occurs that a compositing artist works in 3D. It shouldn't necessarily be complicated modelling, perhaps for example just adding some particles of dust.

The next step in treating a rendering process is about using farm and cloud rendering. It is possible to say that rendering farms are more stuck in the past, especially for small and medium size companies because they are rarely used to their full capacity. Furthermore, such computer clusters are expensive to maintain: they require physical space, consume a lot of power for the use and air conditioning. At the same time, modern internet speed allows for the use of cloud based rendering. Amazon, Microsoft and Google are providing great computing environments at acceptable or even low cost per hour. Users shouldn't be afraid of security because these issues have been dealt with well. Moreover, in comparison with render farms, cloud rendering is affordable not only for companies but also for individual users. (Seymour 2013)

To explain how cloud services work, such renderers as ZYNC can be used as an example. Based on Google's cloud infrastructure, it supports most famous software and plug-ins for visual effects industry. Pricing for Nuke varies from 0.60 to 2.76 dollars per hour depending on machine type. The billing is done on a per-minute basis per machine, with a minimum of 10 minutes. Storage costs 0.20 dollars per gigabyte per month. Users are

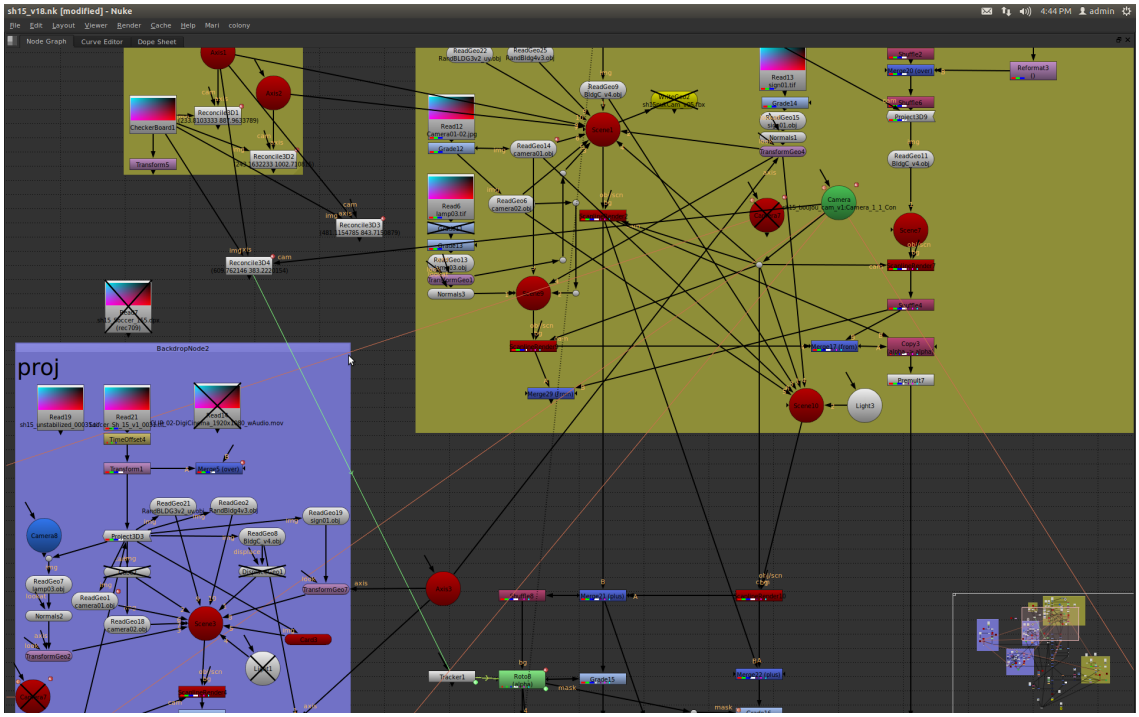
able to calculate approximate time they would require for rendering by using ZYNC's calculator. (ZYNC 2017)

Considering rendering from another angle, modern workstations are powerful enough to do some renders on the background and continue quite comfortably to work on a project. As it was mentioned above, in the "Set a project" sub-chapter, some projects can be set quickly but will need more time to be processed by computer and other way around. Therefore, rendering time can be shortened not only by technical means but also by artists. Of course, on a larger scale and with a lot of 3D elements involved, this advice probably wouldn't effect a great change, but is nonetheless an important thing for every artist to remember. Additionally, to optimise a process, rendering time should be scheduled correctly (e.g. in the end of working day). Good time management in terms of rendering is incredibly important.

3.2 Script building

As was mentioned above, in the compositing software subchapter, scripts in node-based compositing are often referred to as trees which are made from nodes. A well-organized tree can help an artist to work more efficiently. An example in the picture below is possibly a bit exaggerated, but during brainstorming process or when driven by inspiration it is not so hard to create a mess in the script (picture 11). Therefore, it is better to stay organized and follow some rules of scripting in the digital compositing world. It helps the artist to navigate faster in his own scripts, see alternatives better and make decisions faster. Additionally, keeping the script organized and according to the unspoken digital compositing etiquette is essential skill for working in a team.

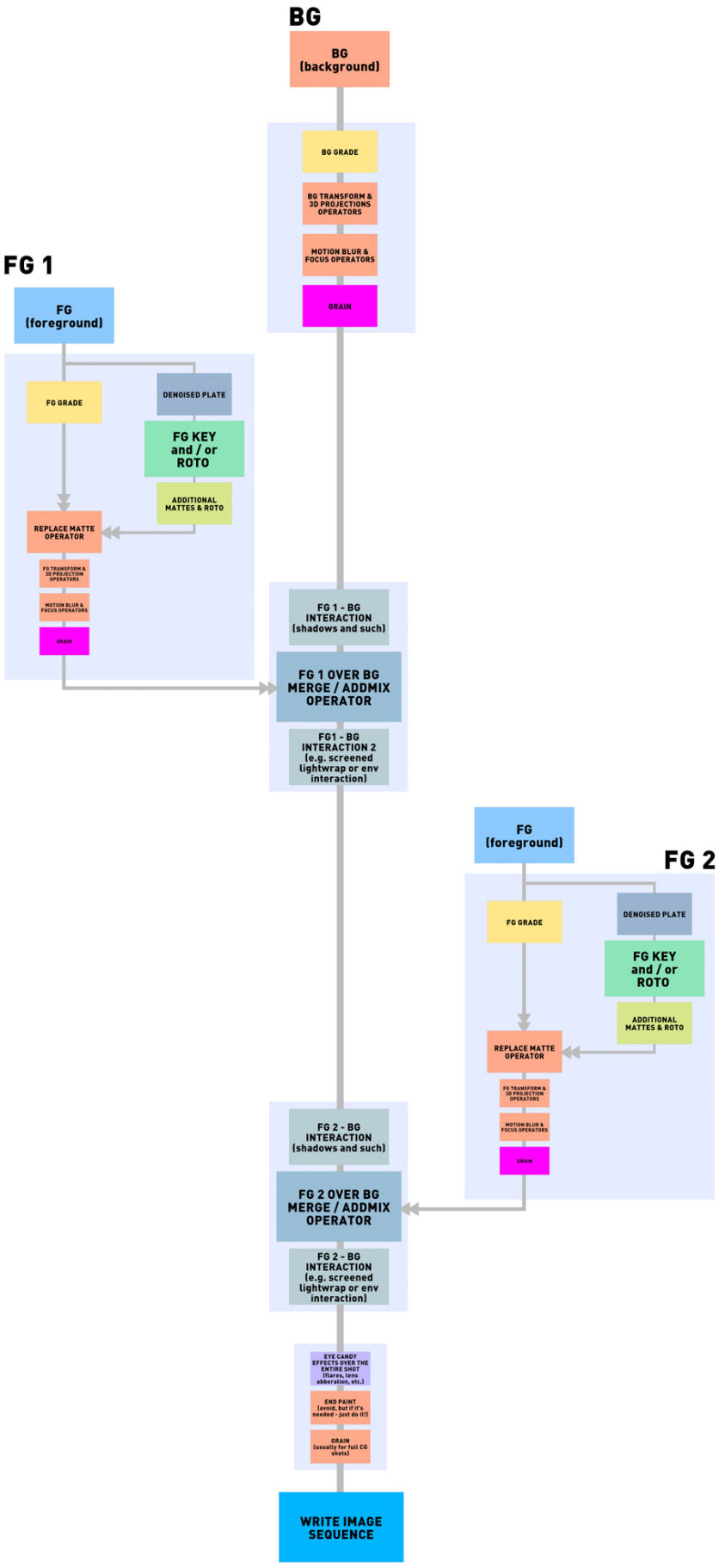
Provided scheme of the script is a great example of how elements should be located inside of the tree (picture 12). The script follows simple logic: background (BG) is always on the top with any required amount of foreground (FG) branched down on the sides. Every foreground branch has one interaction section with the background before merging to the background pipe, and one after merging. Of course, this example is relative and scalable. Some sections can change their locations depending on the project's needs. However, the scheme perfectly demonstrates the idea of how the script, corresponding to the standards of the industry, should flow.



Picture 11. Messy script (Unknown author)

On the image, it is also visible that different sections are grouped together by rectangles which are called backdrops (picture 12, picture 13). An artist can use backdrops of any color to visually separate sections and navigate easier in the script. Mostly, in the industry, artists highlight one specific group of operations by one certain color, and another group by another color in all the scripts. For example, standard color for the Key section is green. The list of colors for specific operations in Nuke can be found in Nukepedia. It is a gizmo called “presetBackdrop” created by Victor Pareze.

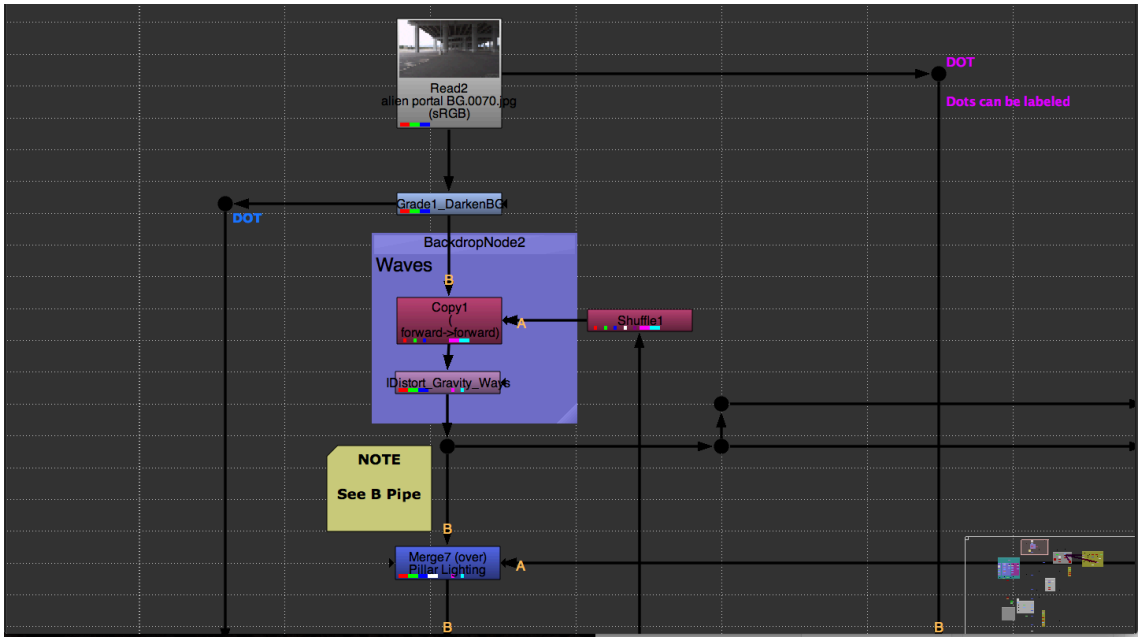
Additionally, groups, notes and dotes are great help to organize scripts. The Group node can nest inside of itself any nodes that an artist chooses. It becomes especially helpful when multiple artists work on the same script. Dotes help to keep screen clean and understandable (picture 13). Notes (a StickyNote node) are just messages an artist can leave for himself or for his team inside of the script (picture 13).



PICTURE 12. Scheme of a script (Djordjevic 2012)

Nuke provides a possibility to personalize color of almost everything inside of the program: layout, arrows, dots, backdrops, nodes. However, artists should be careful with changing colors because it could be in confrontation with industry standards or just confusing for other artists. Especially harmful can be the random coloring of arrows because, by default, Nuke notifies an artist about problems inside of the scripts by red arrows, and about processes occurring by yellow arrows.

Important thing to mention is a rule of a B pipe stream. The script should be organized in such a way that the main branch of the whole script or of sub-sections of the script follows a B connection (Picture 13). Nodes that have more than one input have A and B input arrows, and only B arrows allow information flow downstream even with disabled nodes on the way. B stream preserves metadata, range and format. (Chambers 2010)



PICTURE 13 Example of B pipe, dots, note and backdrop (Pak 2017)

3.2.1 Gizmos

Another great tool to customize Nuke is gizmos which are also nodes that are created by other nodes and wrapped into a custom tool with a user interface, knobs, sliders and on-screen controls. Gizmos allow to avoid repetitive tasks and to create new functionality. (Gandbar 2011, 338)

Every artist can create his own gizmos for faster work. Creation of complicated gizmos might require knowledge of basic programming in Python language. However, a lot of useful gizmos can be downloaded from the Internet. For example, Nukepedia has plenty of gizmos and other useful information for compositing in Nuke. Gizmos have to be installed on computer, which is sometimes problematic. Therefore, when an artist works in an environment where he needs to share his script with other team members, it is better to convert every gizmo to a group. Another scenario of gizmo's use in companies could be that, for example, VFX supervisor creates a gizmo and then pass it to all the workers of the department.

The difference between a group and a gizmo is that a group is something like a "bag" containing many nodes while a gizmo is just behaving as one single node. Also, when a gizmo is converted to a group it is possible to enter inside of the group and see how it works. It can be useful for personalization or for educational purposes. Some default nodes in Nuke, like a LightWrap node, are gizmos, therefore it is nice thing to keep in mind that it is possible to convert these nodes to groups and see how they work. (Perez 2015)

3.2.2 Presets & Toolsets

Some operations or even sets of operations often become repetitive from project to project, therefore if the artist noticed a need to use a node with the same setting in many projects he can create a preset for a node. Next time the node will be used, there will be no need to build all the settings from the beginning. For example, this feature can work perfectly with color correction nodes when the artist could create variety of different color correction presets in advance. It is not only a useful feature for speeding up the work process, but can also provide inspiration and a better understanding of how the final result should look by comparing different presets.

A similar feature to the preset is a toolset or just a template, when group of nodes can be saved and then called in a new project. Toolsets appear in a special menu, and even can be called upon from a shortcut menu. Since a complicated compositing tree consists of blocks of different operations, it becomes incredibly useful to recall some blocks again and again, and then adjust settings according to the artist's need.

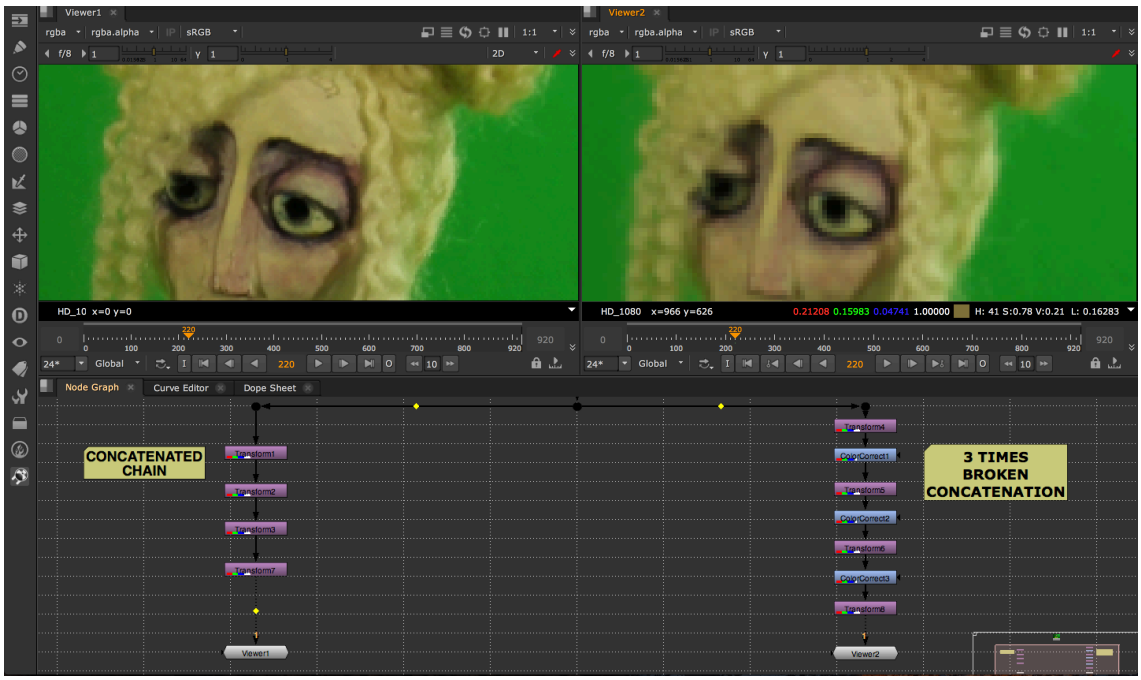
The difference between choosing to use a toolset and group or gizmo is in the style of script building. Toolsets could be used for open structure scripts and groups or gizmos for enclosed structure. However, all of the above-mentioned tools are incredibly important in terms of optimisation because they help to deal with repetitive tasks on which quite often artists need to work. For example, movies and TV shows have plenty repetitive shots. Gizmos, groups, presets and toolsets are great help for a senior compositor who, for instance, needs to manage a whole department of less experienced artists.

3.2.3 Concatenation

Every operation in digital compositing influences image, but transformation nodes also bring unavoidable kick to the image quality. Therefore, when transformation nodes are applied, it is important to remember about such a thing as concatenation. The word concatenation comes from Latin and it means to put things in a chain. Every time transformation is applied it is destroying the image because the program uses filter to redistribute transformed pixels. There are many different filters available in Nuke but in any case, all of them affect quality. Consequently, with an amount of redistributions or transformations the quality of an image decreases. (Pareze 2015)

However, if multiple transformation operations are applied according to the rules of concatenation and the chain is not broken, then Nuke will sum all the operations. For example, if an image was rotated at first to -20 degrees, then to +70, and then to -45, Nuke counts that image should be rotated just to +5 degrees and rotates it once. This means that the program does just one transformation. However, if the chain is broken, Nuke does every rotation as a separate operation. (SphereVFX)

To keep a chain, all transformation operations should be placed together. On the example below, in both situations transformation nodes are equal and, in sum, don’t change rotation and scale (picture 14). However, on the right side of the image the quality is visibly lower because of 3 times broken concatenation. 3 ColorCorrect nodes don’t have any settings and bring no changes to the image, but their position between transformation nodes does.



PICTURE 14. Comparison of concatenation chains (Pak 2017)

All the nodes in Nuke can be divided into 3 groups: those which concatenate up- and downstream, those which concatenate only upstream and those which don't concatenate. It is easy to recognize every category. Usually, nodes that concatenates both ways have filter and motion blur controllers. Upstream nodes have just filter controllers. Those nodes should be positioned at the end of the concatenation chain to not break it. Nodes of the 3rd category have none of the above-mentioned controllers. Nevertheless, every rule has exceptions. A Reformat node has no motion blur but goes into the 1st category of nodes. At the same time, a TransformedMasked node concatenates only upstream but has filter and motion blur knobs. NoOp and Switch nodes are two nodes that don't break concatenation and belong to the 3rd group.

A few more things to remember about concatenation are about filters and motion blur order. Since Nuke sums up all the transformations, there will be only one filter applied to an image. If an artist uses different filters, only the last one in the chain works. When a chain has motion blur applied then no filter will be applied. Motion blur also should be applied correctly. Concatenation with motion blur will work in following cases:

- If all nodes have motion blur on;
- If none of the nodes have motion blur on;

> Once a node has motion blur on, all the following nodes in the chain should have motion blur on as well, and all the previous nodes in the chain should have motion blur off. (Pareze 2015)

In other cases, like off-on-off or on-off-on, the concatenation will be broken.

3.2.4 Expressions

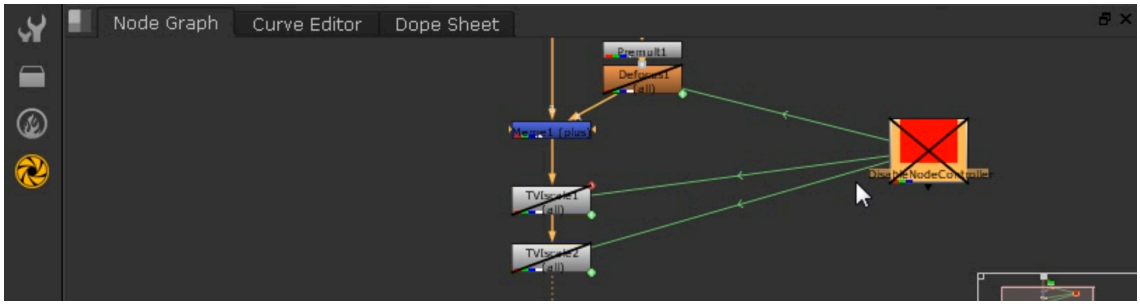
As it was mentioned above Nuke has a lot of possibilities for customization, and the most advanced one is programming intervention. Nuke is written in the C++ and Python programming languages. Every artist can change interface or manipulate nodes on higher levels by using the Python language. Of course, to be a great VFX artist, a person doesn't need to know programming languages, however even without basics of writing codes, an artist can create some small library of expressions that can help to speed up the working process.

Unfortunately, to stay inside of the main topic of the thesis, this subtopic can't be researched deeply, but it is important to remember about programming possibilities in terms of optimisation. Nevertheless, some examples can be outlined.

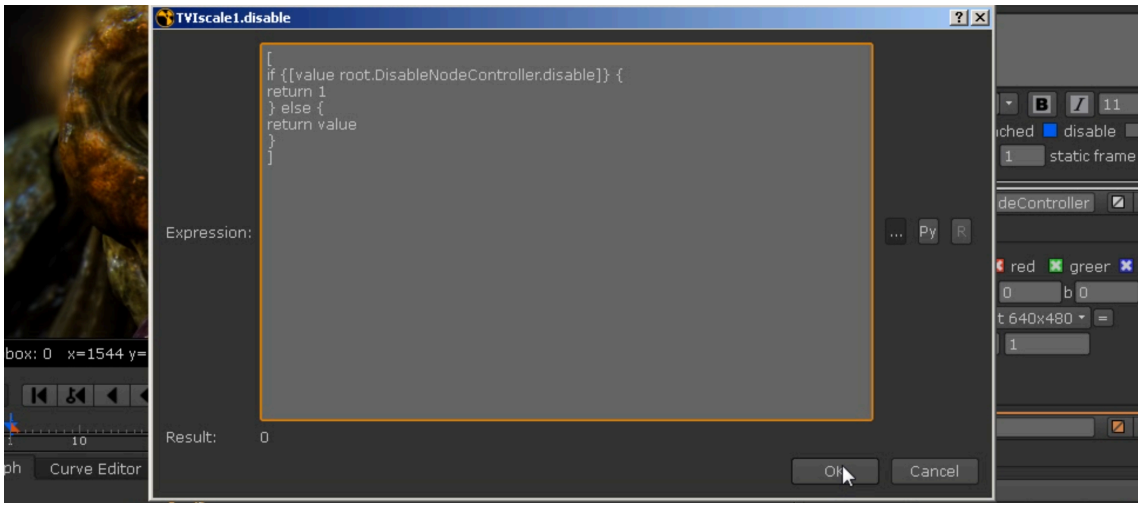
Sometimes situations occur when a need to rename some project folders appears. Consequently, all Nuke's read nodes can't find media files. If it is a big project the amount of missing connections can be huge, and reconnecting files manually takes a lot of time. Therefore, it would be smarter to reconnect all the media with a few lines of code in the Nuke's script editor.

Another example could be a situation with disabling nodes. Every artist, at certain points, needs to disable some nodes. He can do it for different reasons: to lighten up a script by disabling computationally expensive nodes; have variations of the same nodes or sets of nodes; or compare visual results. The problem is that sometimes nodes which were disabled for different reasons are, for example, in the same branch, which creates a mess. Therefore, it is possible to group nodes by disabling reasons by applying a simple expression which creates a control system (Picture 15). On the image below a Constant node is used as a controller, and when it is disabled the rest of the nodes which are linked to the Constant node get disabled as well. All an artist needs to do is to connect the nodes to the

controller by pasting a simple expression (Picture 16). The expression should be added (right mouse click) to disable the controller (node tab) which every node has. “Disable-NodeController” is the name of the Constant node which is controlling other nodes. The name should be written correctly in the expression, otherwise the expression doesn’t need any changes and can be applied to any script. In this way, there could be one controller which is disabling expensive nodes, and another one which is, for example, disabling variations of operations.



PICTURE 15. Example of disabling group of nodes by a controller (Glick 2011)

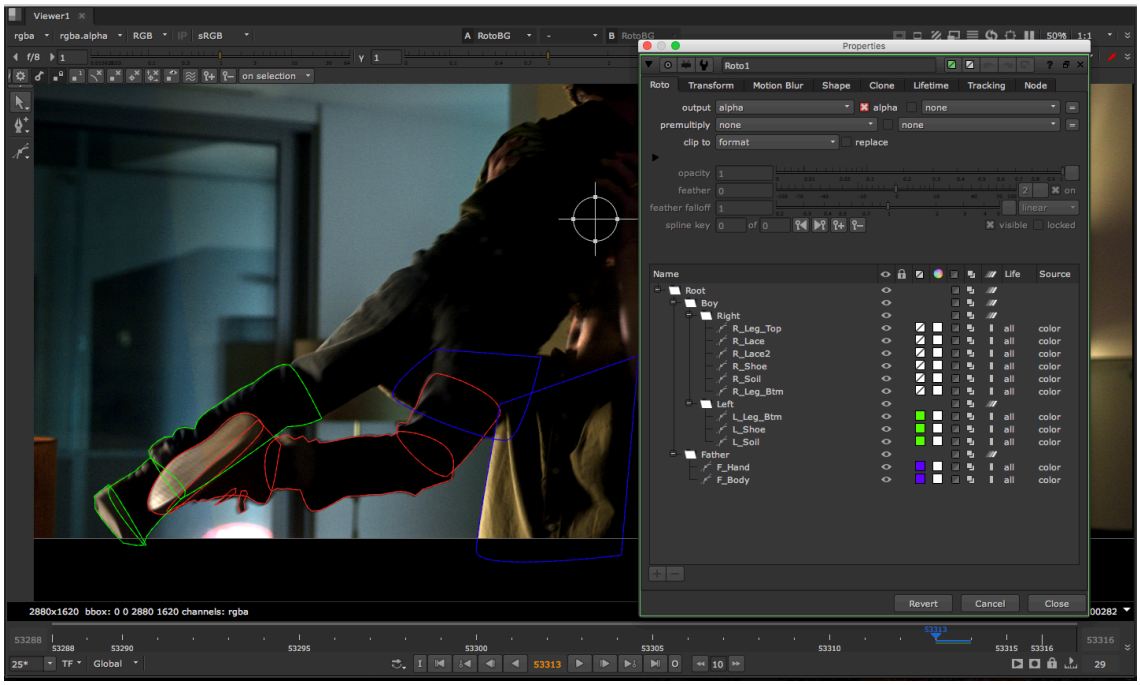


PICTURE 16. Expression for disabling nodes (Glick 2011)

3.3 Rotoscoping

A great part of rotoscoping is animation. Every movement has to be studied and analysed for a smarter and faster roto. If movement is studied well, it allows to put less key points what makes motion more smooth. Scaling, rotating and changing a pivot point are preferable ways to adjust a roto shape. It is better to move separate points seldom as possible.

Often roto nodes can include many shapes. Therefore, it is better to name shapes and put them into corresponding folders. A color of a roto shape is customizable and it could be a useful idea to assign different colors to different categories of shapes (picture 17). These tips help not only an artist who is working on roto but also to other people who might need to pick up a shot.



PICTURE 17. Example of roto (Pak 2016)

Smart use of tracking techniques can speed up rotoscoping process noticeably. Roto shapes can be attached to tracking data, as well as folders with many shapes inside. Additionally, stabilizing and matchmoving a footage can do a great job. Furthermore, checking up rotos on different constant colors helps to improve results and notice mistakes in outlines. It could be useful idea to create a gizmo for roto check-ups. (Brown 2011)

Since rotoscoping is time consuming process, it is important to work in steps and not make every shape perfect. First, every shape has to be made in draft and only after when all shapes are placed and follow main movement of an object is its time to start to polish them. This method of work is important for the VFX pipeline because someone might need to start to work based on roto work. A rotoscoping artist could bring just one perfect part, but waste the time of other artists and be of detriment to a team and production.

4 TECHNICAL OPTIMISATION

4.1 Processing time

Often artists need to work with high resolution files, even bigger than full HD (High Definition) which is 1920x1080 pixels: the most popular standard for broadcasting and the Internet nowadays. For example, the current highest resolution for television and cinematography is named 8K which is 7680x4320 pixels. Obviously, high resolution files slow down the work noticeably. For this reason, during the working process and for preview proxy mode is used.

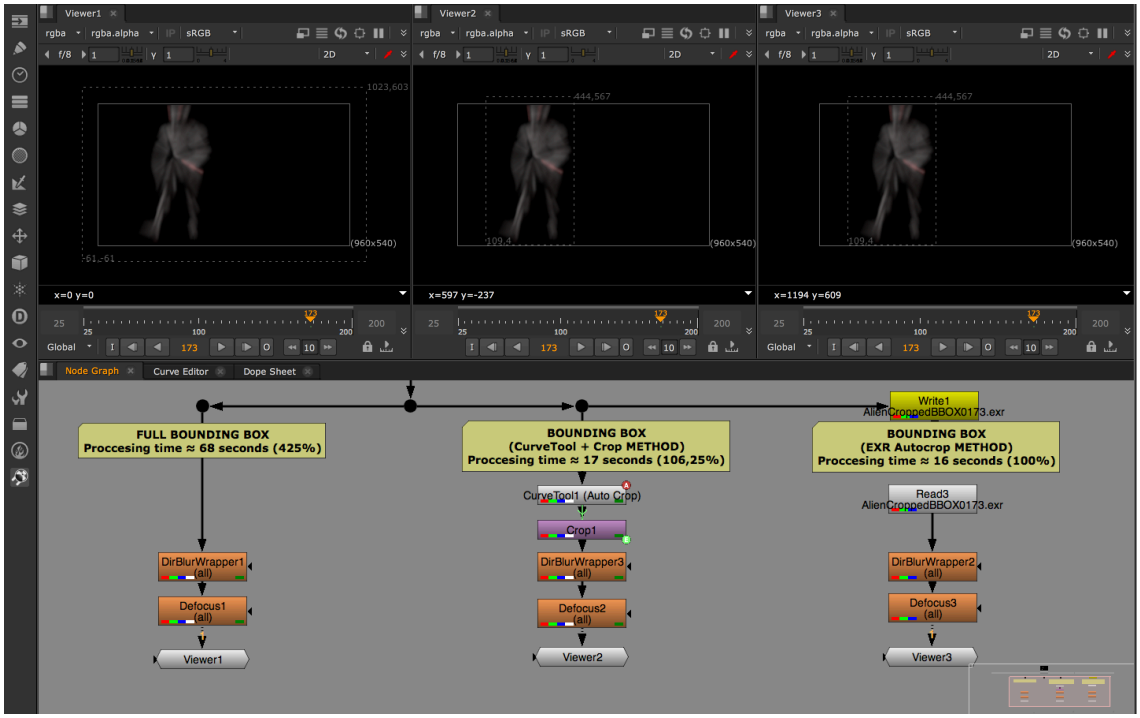
Proxy mode can scale up and down the image on a chosen percentage or change it to a chosen format. Usually it is used for scaling down. An image used in half resolution, respectively, processes twice as fast. For 90% percent of compositing work, when the work needs to be done on a big image, proxy mode can be an incredibly time saving resource.

To make the process even faster, proxy mode can be exported to a separate file and then read back into the script. In this way, the program doesn't need to perform the operation of rescaling original footage internally each time. Additionally, proxy mode should be set in the beginning of the project to, once again, save time.

In some cases, the image with which artist needs to work doesn't fill the whole space in the frame (e.g. 3D or keyed image). At the same time, each image has it is own bounding box which is by default equal to the size of the frame (e.g. 1920x1080), and it becomes even bigger when some operations are applied on the top of the image (e.g. motion blur). However, even if there are black pixels around the image, Nuke applies operations on all the pixels which are inside of the bounding box. Obviously, it increases processing time, and a need to control the bounding box appears.

There are two ways to control the bounding box, and both are based on color information. The first requires the use of a CurveTool node which can automatically calculate crop data that then transfers to a Crop node (picture 18). The second way works only with EXR files, and involves to rerendering the image with an autocrop feature switched on (picture

18). Then, the image with smaller bounding box reads in back in Nuke. Rerendering EXR files with the autocrop reduces the file size to around 30%. Another useful thing about this technique is that most of EXR files which came, for example, from Maya had tile-based rendering, and Nuke prefers scanline-based rendering. Therefore, when EXR files rerendered in Nuke, they became scanline rendered allowing them to be read in faster.



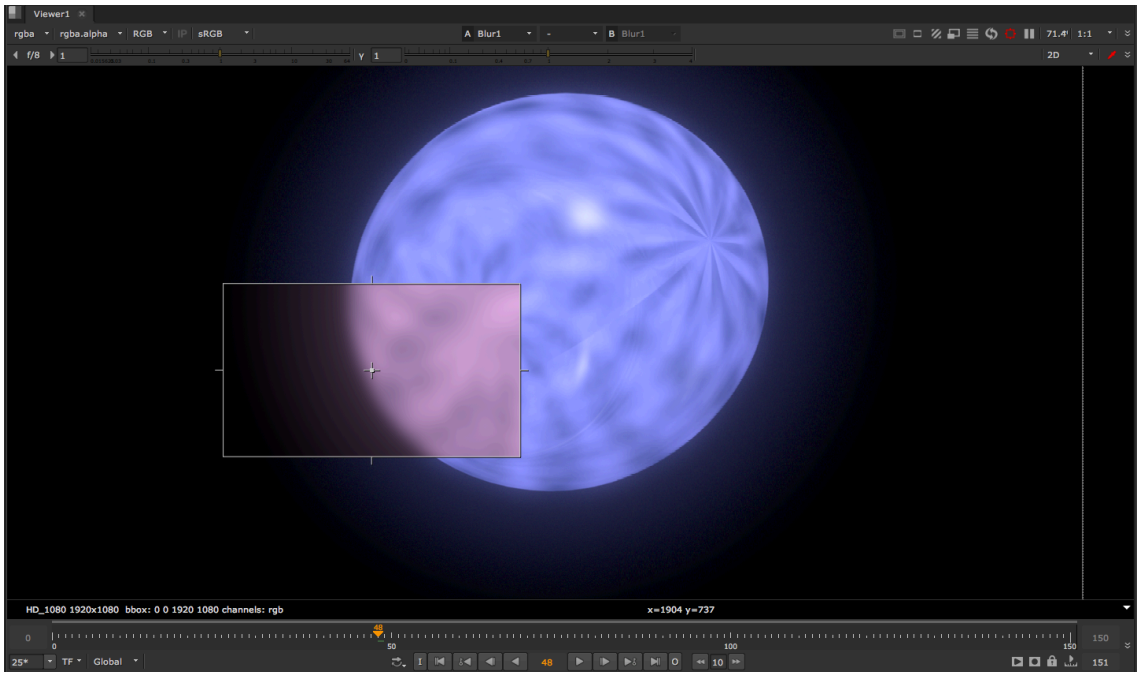
PICTURE 18. Cropping bounding box (Pak 2017)

Nuke is able to support up to 1023 channels per script. This is a huge amount which is rarely used. However, even if a footage has just one more additional channel to typical RGBA, this increases the processing time. Therefore, it is essential to control which channels are needed and which channels can be removed, which can easily be done with a Remove node.

The most typical case of having many channels in a script is to work with 3D. For example, EXR files from 3D department usually come with such channels or ‘passes’ as ambient occlusion, depth of field, beauty pass and many more. Having so many channels gives a compositor great control over the compositing 3D elements. This is called multi-pass compositing, which is a separate chapter in the compositing world.

To clarify the passes and channels terminology, it should be said that passes work as containers that hold channel values, and a channel is just an attribute of an item that can be animated (The Foundry).

Another feature that helps artists to work even faster on some details of the image, is a region of interest which allows the user to select a certain area for rendering in an image. This not only saves rendering time but also helps to see changes in the context with the rest of the image (Picture 19).



PICTURE 19. Region of interest (Pak 2017)

Additionally, even without using region of interest, every time work is done on zoomed image, Nuke only renders the area that fits to the viewer. However, every time the image is paned and new area appears into the viewer, it renders again, which limits this technique's effectiveness.

Another tip that can be incredibly helpful to speed up the processing time is the possibility to disable some computationally expensive nodes, and this topic already has been mentioned in the previous chapter of the thesis. However, disabling nodes technique is used, first of all, to reduce the processing time, which is why it should be reviewed here from another angle.

It would be interesting to understand how much CPU Nuke uses for some of its expensive nodes but, unfortunately, it is not the aim of this thesis and could be quite a controversial topic because the heaviness of every node can grow with its settings. Nevertheless, it is easy to see in the script which nodes slow down the rendering time by exploring the tree from the bottom to the top. With experience, every artist knows which nodes he needs to disable to ease the script. Motion blur, TVI scale, defocus and remapping nodes are great examples of computationally expensive nodes that are better to keep disabled until the final render.

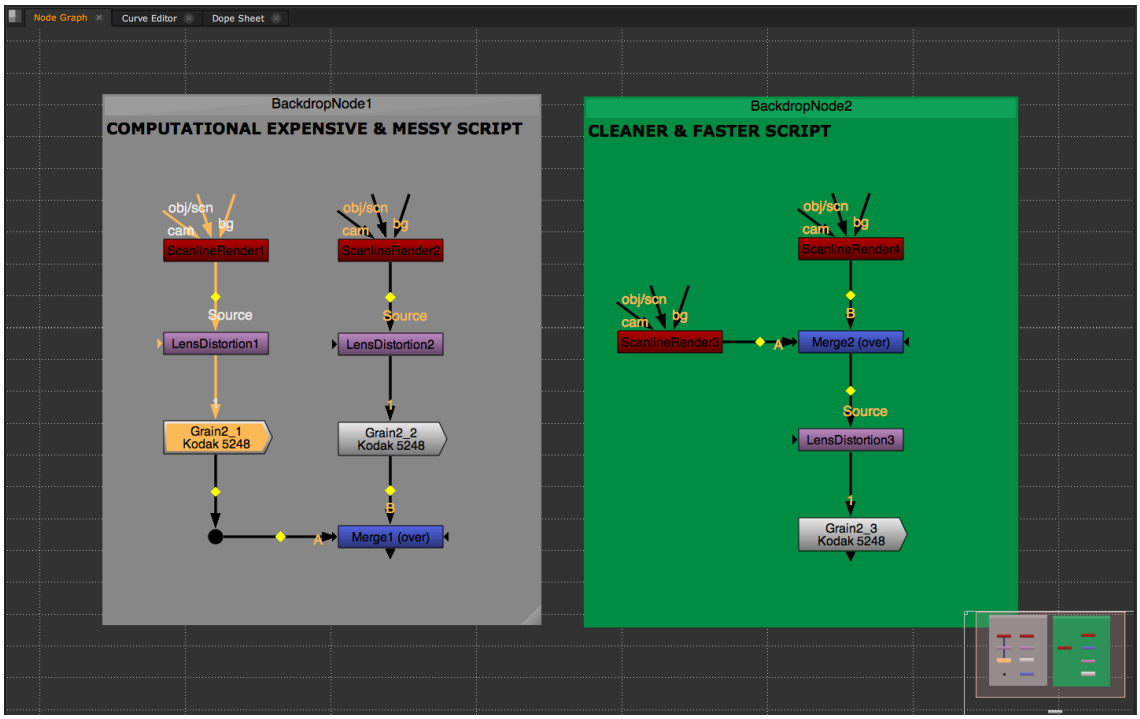
In situations when the script is huge and work on some branches has been already done, it is possible to pre-render some parts of completed work to speed up the final image rendering time. The important thing to remember in this technique is that it is better to pre-render with EXR format. All the required channels should be specified in the write node settings. Alternatively, the DiskCache node can be used in the end of the ready branch. This node also helps to process images faster when they are read in from a network (after a Read node) or when painting or rotoscoping work has to be done (before a RotoPaint node).

Fora faster preview of the final image, every second or third frame of the sequence can be rendered. Playback of the render with skipped frames should have an appropriate frame rate per second (fps). Obviously, with every second frame rendered the rendering time will be halved, with every third – three times less and so on. In situations when renders take hours, it is an incredibly helpful technique to preview the final result.

4.2 Reduction of operations

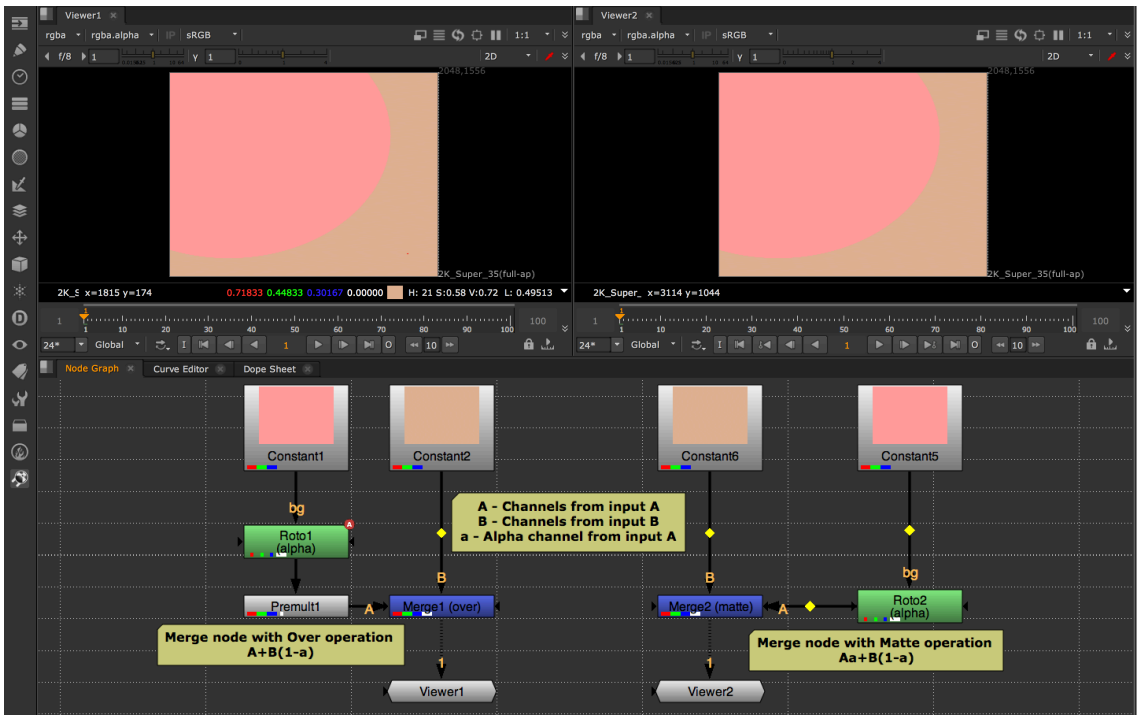
Using as few nodes as possible is always better. It helps to keep script cleaner, and if changes will be needed it is faster to control smaller number of nodes. Also, fewer nodes means a shorter processing time. Creation of lighter scripts should be natural for a compositing artist; natural in the way that he doesn't need to focus on it and is able to occupy his mind with other tasks which are always numerous in the compositing process. It can be hard thing to learn in the beginning, especially considering the time pressures this area has, but is worth it for the future.

For example, it is common situation for color operation nodes to be used on top of each other but in most of the cases it is possible to reduce amount of color operation nodes, and make subsequent fixes faster. Another example is demonstrated in the image below (picture 20). In the situation in the image it seems obvious that it is possible to use just one LensDistortion node and one Grain node. However, when script is big and two ScanlineRender nodes are far from each other, it is easy to miss a possibility to combine two LensDistorions and two Grain nodes which are quite expensive. Developing the example, if there is a possibility to have just one ScanlineRender node then it is better to use it just once.



PICTURE 20. Example of reduction of operations (Pak 2017)

Another tip to reduce operations is the correct use of a Merge node. Generally speaking, this node is a key to building a clear script. By changing operation in a merge node settings, it is always possible to keep a B-Pipe. For example, the right choice of the merge operation on the picture below lets an artist remove an extra Premult node (picture 21).



PICTURE 21. Merge node operations (Pak 2017)

This is the simplest example. If an artist masters all the operations of a merge node he can simplify his work, because it helps him to avoid a lot of additional operations and to keep the script clear. However, even if an artist knows how to smartly use a Merge node operation, he may still prefer not to substitute certain nodes with a Merge node. The reason being that it is sometimes easier to see all the operations in the script as separate nodes.

4.2.1 Substitution

As it was discussed above, it is possible to disable some heavy nodes to decrease the processing time. However, this trick deprives the user of the possibility to view a preview with all the effects. Therefore, some heavy nodes are possible to substitute with less expensive nodes.

For example, a Blur node can be used instead of a Defocus node. Of course, those nodes are not always interchangeable but depending on the requirements an artist can save some processing time. Another example would be in differentiating a RotoPaint node and a Roto node. The Roto node is lighter and faster but, at the same time, has just part of the functionality of the RotoPaint node. Therefore, depending on the purpose, the right node should be chosen. A Card3D node instead of a Card node makes rendering much faster

with a scanline renderer. Additionally, a Grade node can be replaced with a ColorCorrect node. The last one has far more controllers but in many situations, a Grade node can do the job. Generally, a Grade node is designed to color correct film schemes while a ColorCorrect node is designed to match the layers of a composite. (Chambers 2010)

Substitution is not simply the use of one node instead of another. Depending on an artist's preferences, some nodes can be replaced with a set of operations or gizmos. This way can be computationally cheaper or give more controls.

As an example, a LightWrap node can be considered; this node is a gizmo which comes with Nuke by default. However, nobody said that nodes provided by the software developers are perfect or fit to all the conditions. Therefore, it is possible to convert the LightWrap node to a group and edit it or to build own more suitable analogue. (Perez 2015)

5 CONCLUSION

With the incredible number of tools modern software programs provide us with, it is easy to get lost in the beginning and to form bad habits. Therefore, the purpose of this work was to have a great start in digital compositing world, to understand the culture and ethics of this world, and to emphasise that some habits should be formed from the beginning of the career; the habits that will help in the future career of an artist to have right approach to every project, to have an opportunity to work faster and build efficient scripts and to be effective at team working.

In this work, some general tips to optimise workflow were covered - techniques that are useful for every area of compositing. The work could have been called “Introduction to Optimisation” and, as was written in the introduction, some areas are too wide to explore them more deeply in this work. However, they are still outlined here and serve as reminders and inspiration to the reader.

Deeper optimisation is, first of all, hard daily work of each artist and it is exploration of new methods and techniques. Digital compositing is a beautiful combination of visual art, mathematics and logic. Clear, smart and fast scripts are charming and there will always be more than one way to reach the same result.

Adding few more words about optimisation, a problem within the modern compositing world is that people follow new features but don’t have strong knowledge about the basics. Good books about compositing will never replace information from the internet. Of course, the Internet has all the information which is written in a book but it doesn’t have clear structure as book has. Digital compositing world is full of small and big things to know and without structure, it is impossible to cover all the basics: the beginner will just be lost. At the same time, software developers tend to make many operations as automated as possible for faster results and for more comfortable use. Some people are used to pressing the “magic button” without knowing what is behind it, without knowing on what foundation composting is based. Furthermore, the example, provided about a LightWrap node in the sub-chapter about substitution, shows that not all “magic buttons” are perfect. Consequently, there is no space in optimisation for this “magic button” attitude.

The key to optimisation is to be open to new things, stay updated with the new features in compositing world and share ideas. Quite often it happens that one artist inspires another one with some techniques and approaches, who in turn inspires the first artist again. It is endless evaluation and optimisation.

The last and the most important reason to speak about optimisation is art. Digital compositing has become such a technically complicated area that the artistic part of it is weakened or isn't given enough space. These optimisation and efficiency topics are raised in order to help artists to stay artists. Therefore, to finish this work, I would like to quote some words of Senior VFX Supervisor of MPC New York (one of the leading VFX companies) Aleksandar Djordjevic (2012): "We are not a button to be pressed that delivers finished product the industry is trying to make the laymen believe, but a helping, loving and hard-working hand that brings the imagination of the story to the screen and puts it in front of the audience making people fall in love, tremble in fear, or believe aliens are walking among us."

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